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Physiological and yield parameters of noni (*Morinda citrifolia*) as influenced by organic manures and drip irrigation

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An experiment was conducted in *Morinda citrifolia* to find out the effect of various organic manures and drip irrigation on physiological and yield parameters. The experiment was carried out in split plot design with irrigation regimes on main plot and organic manures on sub plot. Among the treatment combinations, M_2S_4 (100% crop water requirement through drip irrigation + 50% farmyard manure + 50% vermicompost) recorded the superior score for leaf area index (0.2597, 0.7755 and 2.0937), light interception (8.65, 11.97 and 17.68%), specific leaf weight (10.89, 12.98 and 12.23 mg cm^{-2}), chlorophyll 'a' (1.483, 1.732 and 1.946 mg g^{-1}), chlorophyll 'b' (0.705, 0.772 and 0.840 mg g^{-1}), total chlorophyll (2.223, 2.554 and 2.818 mg g^{-1}), soluble protein (13.68, 15.84 and 14.42 mg g^{-1}), total phenol (4.55, 6.79 and 5.63 mg g^{-1}) and nitrate reductase activity (38.92, 49.06 and 45.84 µg NO_2 g^{-1} h^{-1}) during vegetative, flowering and harvesting stages respectively. The same treatment combination exhibited the highest yield parameters viz, fruit weight (167.86 g), number of fruits per plant (198.12), yield per plant (33.26 kg).

Key words: *Morinda citrifolia*, farmyard manure, vermicompost, coir pith compost, drip irrigation, physiology, yield.

INTRODUCTION

The availability of irrigation water becomes dwindling day-by-day as such adoption of conventional methods of irrigation to crops leads to an acute scarcity of water and results in reduced production and productivity of crops. Therefore, it becomes imperative to go for alternate water saving methods and income for every drop of water through drip irrigation which provides continuous supply of required water in drops right at the root zone of the crop plant.

By adopting drip irrigation, it is possible to increase the yield potential of crops by three times with the same quantity of water, by saving about 45 to 50% of irrigation water and increasing the productivity by about 40% (Behera et al., 2012).

In the cultivation of modern crop varieties and appropriate management strategies, use of chemical fertilizers have contributed up to 50% raise in food grain output (Braun and Roy, 1983). Despite the key role played by fertilizers, a total dependence on them in achieving a contemplated productivity goal is not fully justified. Furthermore an unabated up rise in the use of chemical fertilizers can inflict irreparable damage to land and environment (Katyal, 1989). Skepticism of nature is being widely exposed in the regions where fertilizer use is already massive. At the same time, any saving in the consumption of chemical fertilizers without affecting the productivity is a social necessity. Measurable decrease in fertilizer consumption without compromising the yield and

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quality can also be made practically possible through organic inputs.

Large scale cultivation under organic conditions is gaining momentum to produce toxic free medicinal plant products (Padmanabhan, 2003). Organically grown herbal materials are more preferred in the herbal preparations since they are more effective and safe. Organic farming provides better and balanced environment, better food and living conditions to the human beings (Baby, 2012).

One upcoming botanical name, the fruit of *Morinda citrifolia* very popularly known as noni belongs to the family Rubiaceae. Indigenous to South East Asia, noni was domesticated and cultivated by Polynesians. The tree grows rigorously from India to Malaysia, Fiji and Polynesia (Mathivanan et al., 2005).

Noni is the biggest pharmaceutical unit in the universe because it has more than 160 nutraceuticals, vitamins, minerals, micro and macro nutrients that help the body in various ways from cellular level to organ level (Rethinam and Sivaraman, 2007). The fruit juice is in high demand in alternative medicine for different kinds of illnesses such as arthritis, diabetes, high blood pressure, muscle aches, menstrual difficulties, headaches, heart disease, AIDS, cancers, gastric ulcers, sprains, mental depression, senility, poor digestion, atherosclerosis, blood vessel problems and drug addiction (Wang et al., 2002).

The purpose of this medicinal herb will be fulfilled only if it is free from residual effects due to chemical farming. Hence, the study was undertaken to find out best organic nutrition schedule along with irrigation regimes for (Table 2) obtaining highest (Table 3) yield through improved physiological parameters.

MATERIALS AND METHODS

This study was conducted at Horticultural College and Research Institute, TNAU, Periyakulam, Tamil Nadu, India which is situated at 77ºE longitude, 10ºN latitude and at an altitude of 300 m above mean sea level.

Methodology

The plants were obtained from World Noni Research Foundation, Chennai, India. The experimental design is as shown in Table 1.

Treatment details

All organic manures were applied on equivalent weight of RDN (60 g/plant/year - on N equivalent basis). The treatments S1 to S6 are applied with Azospirillum (10 g/ plant) + phosphobacteria (10 g/ plant) + VAM (20 g/ plant).

Crop water requirement (WRc)

Crop water requirement was calculated by using the following formula before every irrigation.

$$WRc = P_e \times K_p \times K_c \times A \times WP \text{ liter/plant/day}$$

Where, P_e = Pan evaporation in mm; K_p = Pan Co-efficient (0.75); K_c = Crop factor (0.90 for vegetative stage, 0.95 for flowering and harvesting stage); A = Area occupied by the tree (3.6 m × 3.6 m), and WP = wetted percentage (40).

Observations

Physiological parameters

Leaf area index (LAI): The leaf area index was worked out by the method suggested by Williams (1946).

$$LAI = \frac{\text{Total leaf area per plant}}{\text{Ground area occupied}}$$

Light interception (LI): The percent light interception in the canopy was calculated by comparison with a Lux meter placed in the open sunny situation every day. The measurement was made between 12.00 and 14.00 hours as per the method suggested by Nelliat et al. (1974) and expressed in %.

$$LI\ (\%) = \frac{\text{Mean of light intensity at middle of the canopy and ground level}}{\text{Light intensity in the open}} \times 100$$

Specific leaf weight (SLW): The specific leaf weight was calculated using the formula postulated by Pearce et al. (1968) and expressed as mg cm^{-2}.

$$SLW = \frac{\text{Leaf dry weight}}{\text{Leaf area}}$$

Chlorophyll content: Fresh leaves from each treatment were collected and the chlorophyll 'a' and 'b' and total chlorophyll contents were determined by the method suggested by Yoshida et al. (1971) and expressed as mg g^{-1} of fresh weight.

Soluble protein: Soluble protein was extracted with phosphate buffer and estimated as per the method described by Lowry et al. (1951) and the same was expressed in mg g^{-1} fresh weight.

Total phenol content: The total phenol content of the fresh leaves was estimated by the method suggested by Bray and Thorpe (1954) using Folin Ciocalteu reagent and expressed as mg g^{-1} material.

Nitrate reductase activity: The nitrate reductase activity of leaf samples was estimated using the method described by Sinha and Nicholas (1981). The values were expressed as µg NO_2 g^{-1} h^{-1} on wet weight basis.

Yield parameters

Fruit weight: The whole weight of ten fruits was taken and their mean weight was expressed in grams (g).

Number of fruits per plant: The number of fruits harvested from each plant over several harvests were counted and expressed in number.

Fruit yield per plant: The yield was recorded after weighing fully matured fruits at each harvest, summed and expressed in kilograms per plant.

Table 1. Design of experiment.

Statistical design	Split plot design
Factors	2
Replications	2
Spacing	3.6 m × 3.6 m
Number of plants per replication	5

Table 2. Main plot (Irrigation).

M_1	75% WRc (Crop water requirement through drip irrigation)
M_2	100% WRc (Crop water requirement through drip irrigation)
M_3	125% WRc (Crop water requirement through drip irrigation)
M_4	Check basin method of irrigation (once in 5 days)

Table 3. Sub plot (Organic manures).

S_1	100% Farmyard manure (FYM)
S_2	100% vermicompost (VC)
S_3	100% coir pith compost (CPC)
S_4	50% FYM + 50% VC
S_5	50% FYM + 50% CPC
S_6	50% VC + 50% CPC
S_7	100% recommended dose of nitrogen (RDN) through inorganic fertilizers
S_8	Control (no manures and no fertilizers)

Statistical analysis

The statistical analysis of data was done by adopting the standard procedures of Panse and Sukhatme (1985). The AGRES software (version 3.01) was used for analysis of data.

RESULTS

Physiological parameters

Leaf area index (LAI)

There is a linear increase in LAI from vegetative to harvesting stage (Table 4). Among the main plot treatments application of 100% WRc through drip irrigation (M_2) was found to have significant influence on the LAI at various stages of crop growth. An increased LAI (0.1826, 0.5376 and 1.3427) in vegetative, flowering and harvesting stages respectively was observed in the treatment M_2 (100% WRc through drip irrigation) and this was followed by M_3 (125% WRc through drip irrigation) with LAI of 0.1778, 0.5273 and 1.3107. The LAI was found to be the lowest in the M_4 (check basin method of irrigation) during vegetative (0.0661), flowering (0.1780) and harvesting (0.5171) stages.

Between the sub plots, S_4 (50% FYM + 50% VC) recorded the superior performance for LAI (0.1777, 0.5260 and 1.3868) in vegetative, flowering and harvesting stages respectively and this was followed by S_2 (100% VC) with LAI of 0.1625, 0.4807 and 1.2258. The treatment S_8 (no manures and no fertilizers) registered the lowest score for LAI (0.0457, 0.1133 and 0.3211) in different stages of crop growth.

The experimental plots receiving 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) produced the highest LAI of 0.2597, 0.7755 and 2.0937 in vegetative, flowering and harvesting stages respectively and this was followed by M_3S_4 (125% WRc through drip irrigation + 50% FYM + 50% VC) with LAI of 0.2408, 0.7239 and 1.8706. While the lowest LAI (0.0350, 0.0902 and 0.2559) was recorded from the treatment combination M_4S_8 (check basin method of irrigation + no manures and no fertilizers).

Light interception

There was a proportionate increase in light interception in all the treatments as the age of the crop advanced (Table 5). Among the main plots, the treatment M_2 (100% WRc through drip irrigation) recorded the highest light interception

Table 4. Effect of different water regimes and organic manures on leaf area index.

Treatment	Vegetative stage					Flowering stage					Harvesting stage				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	0.1055	0.1861	0.1799	0.066	0.1344	0.2808	0.5387	0.5396	0.1754	0.3836	0.8067	1.2851	1.3371	0.5218	0.9877
S_2	0.1231	0.2222	0.2306	0.0742	0.1625	0.3385	0.6776	0.6973	0.2094	0.4807	0.8959	1.6548	1.7490	0.6036	1.2258
S_3	0.0931	0.1549	0.1494	0.0600	0.1144	0.2496	0.4561	0.4309	0.1464	0.3208	0.7183	1.0681	1.0198	0.4399	0.8115
S_4	0.1285	0.2597	0.2408	0.0818	0.1777	0.3736	0.7755	0.7239	0.2310	0.5260	0.9280	2.0937	1.8706	0.6548	1.3868
S_5	0.0982	0.1706	0.1664	0.0641	0.1248	0.2691	0.4973	0.4834	0.1602	0.3525	0.7631	1.2011	1.1375	0.4758	0.8944
S_6	0.1168	0.2157	0.2090	0.0697	0.1528	0.3120	0.6401	0.6246	0.1878	0.4411	0.8426	1.5941	1.5453	0.5634	1.1364
S_7	0.1371	0.2003	0.1970	0.0778	0.1531	0.4032	0.5886	0.5968	0.2239	0.4531	0.9733	1.4718	1.4832	0.6216	1.1375
S_8	0.0465	0.0515	0.0496	0.0350	0.0457	0.1149	0.1267	0.1215	0.0902	0.1133	0.3125	0.3729	0.3432	0.2559	0.3211
Mean	0.1061	0.1826	0.1778	0.0661	0.1332	0.2927	0.5376	0.5273	0.1780	0.3839	0.7801	1.3427	1.3107	0.5171	0.9876
	M	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**	
SE(d)	0.001	0.001	0.002	0.002		0.003	0.003	0.006	0.006		0.006	0.008	0.016	0.016	
CD at 5%	0.003	0.002	0.005	0.004		0.008	0.006	0.014	0.013		0.020	0.016	0.036	0.032	

Table 5. Effect of different water regimes and organic manures on light interception (%).

Treatment	Vegetative stage					Flowering stage					Harvesting stage				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	6.28	7.59	7.50	5.59	6.74	9.12	10.83	10.74	8.03	9.68	13.90	16.26	16.15	12.20	14.63
S_2	6.61	8.20	8.36	5.70	7.22	9.53	11.42	11.58	8.18	10.18	14.32	16.93	17.12	12.36	15.18
S_3	6.10	7.12	7.03	5.43	6.42	8.95	10.28	10.24	7.84	9.33	13.69	15.65	15.57	11.88	14.20
S_4	6.68	8.65	8.47	5.86	7.42	9.62	11.97	11.73	8.39	10.43	14.38	17.68	17.35	12.65	15.52
S_5	6.23	7.34	7.19	5.50	6.57	9.06	10.52	10.40	7.91	9.47	13.83	15.96	15.79	12.02	14.40
S_6	6.47	8.05	7.92	5.65	7.02	9.34	11.27	11.15	8.12	9.97	14.15	16.73	16.59	12.27	14.94
S_7	6.75	7.80	7.74	5.76	7.01	9.68	10.97	10.92	8.28	9.96	14.49	16.41	16.34	12.54	14.95
S_8	4.79	4.99	4.91	4.60	4.82	6.68	6.95	6.82	6.39	6.71	10.40	10.75	10.59	9.94	10.42
Mean	6.24	7.47	7.39	5.51	6.65	9.00	10.53	10.45	7.89	9.47	13.65	15.80	15.69	11.98	14.28
	M	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**	
SE(d)	0.037	0.048	0.097	0.096		0.051	0.069	0.138	0.137		0.077	0.103	0.208	0.207	
CD at 5%	0.117	0.099	0.215	0.197		0.163	0.141	0.304	0.281		0.244	0.212	0.458	0.423	

(7.47, 10.53 and 15.80%) in vegetative, flowering and harvesting stages respectively. Among the main plots, M_4 (check basin method of irrigation) exhibited the lowest light interception (5.51, 7.89 and 11.98%) in all stages of crop growth.Among the sub plot treatments, S_4 (50% FYM + 50% VC) exhibited the superior performance with 7.42, 10.43 and 15.52% light interception during vegetative, flowering and harvesting stages respectively (Table 6). The lowest light interception of 4.82, 6.71 and 10.42% was recorded with no manures and no fertilizers treatment (S_8). Among the interactions, the treatment combination M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) registered the highest light interception in vegetative (8.65%), flowering (11.97%) andharvesting (17.68%) stages which is on par with M_3S_4 (125% WRc through drip irrigation + 50% FYM + 50% VC) which showed light interception of 8.47, 11.73 and 17.35% in different stages of crop growth. Check basin method of irrigation + no manures and no fertilizers (M4S8) treatment combination exhibited the lowest light interception in vegetative (4.60%), flowering (6.39%) and harvesting (9.94%) stages.

Specific leaf weight (SLW)

Among the main plot, M2 (100% WRc through drip irrigation) exhibited the highest SLW (9.35, 11.12 and 10.49 mg cm^{-2}) during vegetative, flowering and harvesting stages. SLW was found to be the lowest in the M4 (check basin method of irrigation) during vegetative (7.20 mg cm^{-2}), flowering (8.14 mg cm^{-2}) and harvesting (7.57 mg cm^{-2}) stages.

Among the manure treatments, application of 50% FYM + 50% VC (S_4) had resulted in the highest SLW of 9.31, 11.00 and 10.32 mg cm^{-2}. While S_8 (no manures and no fertilizers) registered the least score for SLW (6.41, 7.06 and 6.71 mg cm^{-2}).

Between the interactions, the treatment combination, M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) recorded the utmost SLW (10.89, 12.98 and 12.23 mg cm^{-2}) in vegetative, flowering and harvesting stages respectively and this was followed by M_3S_4 (125% WRc through drip irrigation + 50% FYM + 50% VC) with SLW of 10.21, 12.26 and 11.67 mg cm^{-2} in various crop growth stages. Whereas the lowest SLW in vegetative (6.02 mg cm^{-2}), flowering (6.43 mg cm^{-2}) and harvesting (6.28 mg cm^{-2}) stages was noticed from the treatment M_4S_8 (check basin method of irrigation + no manures and no fertilizers).

Chlorophyll 'a'

Among the main plot treatments provision of 100% WRc through drip irrigation (M_2) was found to have profound influence on the chlorophyll content in all the stages and this treatment recorded the highest chlorophyll'a' (Table 7) content in vegetative (1.310 mg g^{-1}), flowering (1.516 mg g^{-1}) and harvesting (1.693 mg g^{-1}) stages. While the lowest chlorophyll content of 1.111, 1.244 and 1.365 mg g^{-1} was registered in the treatment M_4 (check basin method of irrigation).

Application of 50% FYM + 50% VC (S_4) recorded the highest chlorophyll content (1.329, 1.538 and 1.711 mg g^{-1}) during vegetative, flowering and harvesting stages respectively and this was followed by S_2 (100% VC) with chlorophyll content of 1.302, 1.496 and 1.662 mg g^{-1} in various stages of crop growth. The least score for chlorophyll content (0.917, 1.012 and 1.109 mg g^{-1}) was recorded with S_8 (no manures and no fertilizers).

Among the interaction effects, the treatment combination M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) recorded the superior scores for chlorophyll 'a' content (1.483, 1.732 and 1.946 mg g^{-1}) in vegetative, flowering and harvesting stages respectively and this was followed by M_3S_4 (125% WRc through drip irrigation + 50% FYM + 50% VC) with 1.416, 1.644 and 1.826 mg g^{-1} in vegetative, flowering and harvesting stages. The treatment combination M_4S_8 (check basin method of irrigation + no manures and no fertilizers) exhibited poor performance for chlorophyll 'a' content (0.872, 0.961 and 1.057 mg g^{-1}) in various stages of crop growth.

Chlorophyll 'b'

Application of 100% WRc through drip irrigation (M_2) recorded the highest chlorophyll 'b' content in vegetative0.584 mg g^{-1}), flowering (0.624 mg g^{-1}) and harvesting (0.664 mg g^{-1}) stages. While the treatment M_4 (check basin method of irrigation) recorded the lowest content of chlorophyll 'b' with 0.409, 0.439 and 0.460 mg g^{-1} in vegetative, flowering and harvesting stages respectively.

Application of 50% FYM + 50% VC (S_4) recorded the highest content of chlorophyll 'b' with 0.591, 0.641 and 0.684 mg g^{-1} in vegetative, flowering and harvesting stages respectively. Whereas, the lowest chlorophyll 'b' content was recorded with S_8 (no manures and no fertilizers) with 0.303, 0.321 and 0.333 mg g^{-1} in various stages of crop growth.

Between the interaction, the treatment combination, M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) recorded the utmost chlorophyll 'b' content (0.705, 0.772 and 0.840 mg g^{-1}) in vegetative, flowering and harvesting stages respectively and this was followed by M_3S_4 (125% WRc through drip irrigation + 50% FYM + 50% VC) with chlorophyll 'b' content of 0.677, 0.725 and 0.781 mg g^{-1} in various crop growth stages. Whereas the lowest chlorophyll 'b' in vegetative (0.246 mg g^{-1}), flowering (0.262 mg g^{-1}) and harvesting (0.275 mg g^{-1}) stages was noticed from the treatment M_4S_8 (check basin method of irrigation + no manures and no fertilizers).

Total chlorophyll

Among the irrigation regimes application of 100% WRc through drip irrigation (M_2) recorded the highest total chlorophyll content in vegetative (1.927 mg g^{-1}), flowering (2.172 mg g^{-1}) and harvesting (2.370 mg g^{-1}) stages while check basin method of irrigation (M_4) recorded the lowest score for total chlorophyll content (1.540, 1.690 and 1.832 mg g^{-1}) in the entire crop growth period (Table 9). Among the manure treatments, application of 50% FYM + 50% VC (S_4) recorded the highest total chlorophyll content (1.951, 2.206 and 2.412 mg g^{-1}) in vegetative, flowering and harvesting stages respectively and this was followed by application of 100% VC (S_2) with 1.908, 2.127 and 2.324 mg g^{-1} of total chlorophyll content in various crop growth stages. The lowest total chlorophyll content of 1.228, 1.340 and 1.449 mg g^{-1} was noticed from the treatment S_8 (no manures and no fertilizers) in vegetative, flowering and harvesting stages respectively. Among the interactions, the treatment combination M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) registered the highest total chlorophyll content in vegetative (2.223 mg g^{-1}), flowering (2.554 mg g^{-1}) and harvesting (2.818 mg g^{-1}) stages and this was followed by M_3S_4 (125% WRc through drip irrigation + 50% FYM + 50% VC) with total chlorophyll content of 2.142, 2.407 and 2.624 mg g^{-1} in different stages of crop growth. Check basin method of irrigation + no manures and no fertilizers (M_4S_8) treatment combination exhibited the lowest total chlorophyll content in vegetative (1.129 mg g^{-1}), flowering (1.231 mg g^{-1}) and harvesting (1.339 mg g^{-1}) stages.

Soluble protein

In all the treatments soluble protein content increased from vegetative to flowering stage and decreased towards the harvesting stage (Table 10). Among the main plot, M_2 (100% WRc through drip irrigation) exhibited superior performance for soluble protein content (11.90, 13.80 and 12.55 mg g^{-1}) during vegetative, flowering and harvesting stages respectively. The soluble protein content was found to be the lowest in the treatment M_4 (check basin method of irrigation) during vegetative (9.23 mg g^{-1}), flowering (10.15 mg g^{-1}) and harvesting (9.45 mg g^{-1}) stages. In the sub plot, the treatment, S_4 (50% FYM + 50% VC) recorded the highest soluble protein content (12.02, 13.79 and 12.54 mg g^{-1}) in vegetative, flowering and harvesting stages respectively. While the treatment S_8 (no manures and no fertilizers) registered the lowest score for soluble protein content (7.48, 8.14 and 7.68 mg g^{-1}) in all stages of crop growth. In the interaction, the treatment combination M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) recorded the highest soluble protein content in vegetative (13.68 mg g^{-1}), flowering (15.84 mg g^{-1}) and harvesting (14.42 mg g^{-1}) stages and this was followed by M_3S_4 (125% WRc through drip irrigation + 50% FYM + 50% VC) with soluble protein content of 13.21, 15.36 and 13.88 mg g^{-1} in various stages of crop growth. The lowest soluble protein content of 6.24, 6.71 and 6.39 mg g^{-1} was registered in the treatment combination M_4S_8 (check basin method of irrigation + no manures and no fertilizers).

Total phenol

Total phenol content increased from vegetative to flowering stage and decreased thereafter (Table 11). Among the main plot, M_2 (100% WRc through drip irrigation) registered the highest total phenol content in vegetative (3.92 mg g^{-1}), flowering (5.92 mg g^{-1}) and harvesting (4.76 mg g^{-1}) stages. The total phenol content was found to be the lowest (2.82, 4.07 and 2.76 mg g^{-1}) in the treatment comprising check basin method of irrigation (M_4).

Regarding the sub plot treatments, the highest total phenol content in vegetative (3.92 mg g^{-1}), flowering (5.80 mg g^{-1}) and harvesting (4.61 mg g^{-1}) stages was recorded from the treatment comprising 50% FYM + 50% VC (S_4). The lowest total phenol content of 2.33, 3.16 and 1.90 mg g^{-1} was recorded from the treatment S_8 (no manures and no fertilizers) during various crop growth stages.

Among the interaction effects, the treatment combination M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) registered the highest total phenol content of leaves in vegetative (4.55 mg g^{-1}), flowering (6.79 mg g^{-1}) and harvesting (5.63 mg g^{-1}) stages and this was followed by M_3S_4 with 4.41, 6.62 and 5.49 mg g^{-1}. Whereas lowest total phenol content (2.13, 2.89 and 1.60 mg g^{-1}) was observed from M_4S_8 (check basin method of irrigation + no manures and no fertilizers).

Nitrate reductase

Among the main plot treatments, M_2 (100% WRc through drip irrigation) recorded the highest nitrate reductase activity (32.88, 39.61 and 35.00 µg NO_2 g^{-1} h^{-1}) in vegetative, flowering and harvesting stages respectively (Table 12). Whereas the lowest nitrate reductase activity (22.22, 23.89 and 18.61 µg NO_2 g^{-1} h^{-1}) was noticed from treatment comprising check basin method of irrigation (M_4).

Regarding the sub plots, application of 50% FYM + 50% VC (S_4) exhibited the superior scores for nitrate reductase activity (32.02, 38.28 and 33.35 µg NO_2 g^{-1} h^{-1}) followed by application of 100% VC (S_2) with 30.91, 36.28 and 31.31 µg NO_2 g^{-1} h^{-1}. While the treatment S_8 (no manures and no fertilizers) showed very poor performance for nitrate reductase activity with 16.79, 17.97 and 14.08 µg NO_2 g^{-1} h^{-1} in vegetative, flowering and harvesting stages respectively.

Among the interactions, the treatment combination

Table 6. Effect of different water regimes and organic manures on specific leaf weight (mg cm^{-2}).

Treatment	Vegetative stage					Flowering stage					Harvesting stage				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	8.26	9.55	9.43	7.30	8.64	9.52	11.29	11.23	8.22	10.07	9.01	10.68	10.60	7.68	9.49
S_2	8.54	10.02	10.09	7.44	9.02	10.03	12.10	12.15	8.48	10.69	9.36	11.49	11.55	7.79	10.05
S_3	8.07	8.94	9.02	7.13	8.29	9.31	10.89	10.92	8.10	9.81	8.79	10.16	10.23	7.54	9.18
S_4	8.60	10.89	10.21	7.53	9.31	10.12	12.98	12.26	8.62	11.00	9.48	12.23	11.67	7.88	10.32
S_5	8.12	9.22	9.29	7.22	8.46	9.26	11.04	11.16	8.14	9.90	8.83	10.30	10.44	7.60	9.29
S_6	8.32	9.89	9.80	7.38	8.85	9.69	11.79	11.65	8.40	10.38	9.07	11.19	11.12	7.73	9.78
S_7	8.39	9.64	9.74	7.59	8.84	9.80	11.44	11.52	8.73	10.37	9.22	10.91	10.96	8.06	9.79
S_8	6.46	6.63	6.54	6.02	6.41	7.11	7.40	7.29	6.43	7.06	6.71	6.96	6.87	6.28	6.71
Mean	8.10	9.35	9.27	7.20	8.48	9.36	11.12	11.02	8.14	9.91	8.81	10.49	10.43	7.57	9.32
	M	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**	
SE(d)	0.046	0.061	0.123	0.122		0.054	0.072	0.145	0.144		0.051	0.068	0.136	0.135	
CD at 5%	0.146	0.125	0.272	0.251		0.171	0.147	0.319	0.294		0.163	0.138	0.301	0.277	

Table 7. Effect of different water regimes and organic manures on chlorophyll ‘a’ (mg g^{-1}) content of noni leaves.

Treatment	Vegetative stage					Flowering stage					Harvesting stage				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	1.227	1.329	1.342	1.135	1.258	1.409	1.542	1.554	1.279	1.446	1.573	1.729	1.734	1.410	1.612
S_2	1.253	1.392	1.405	1.159	1.302	1.432	1.621	1.633	1.296	1.496	1.603	1.807	1.817	1.422	1.662
S_3	1.207	1.289	1.280	1.103	1.220	1.395	1.503	1.492	1.243	1.408	1.558	1.688	1.662	1.356	1.566
S_4	1.244	1.483	1.416	1.172	1.329	1.446	1.732	1.644	1.329	1.538	1.614	1.946	1.826	1.458	1.711
S_5	1.215	1.318	1.309	1.119	1.240	1.386	1.520	1.538	1.256	1.425	1.532	1.706	1.716	1.376	1.583
S_6	1.239	1.384	1.372	1.146	1.285	1.424	1.610	1.598	1.270	1.476	1.586	1.794	1.780	1.398	1.640
S_7	1.264	1.353	1.361	1.179	1.289	1.453	1.569	1.574	1.314	1.478	1.629	1.746	1.752	1.443	1.643
S_8	0.918	0.932	0.947	0.872	0.917	1.012	1.031	1.042	0.961	1.012	1.109	1.129	1.142	1.057	1.109
Mean	1.196	1.310	1.304	1.111	1.230	1.370	1.516	1.509	1.244	1.410	1.526	1.693	1.679	1.365	1.566
	M	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**	
SE(d)	0.007	0.009	0.018	0.018		0.007	0.010	0.021	0.020		0.008	0.011	0.023	0.023	
CD at 5%	0.021	0.018	0.039	0.036		0.024	0.021	0.045	0.042		0.026	0.023	0.050	0.046	

Table 8. Effect of different water regimes and organic manures on chlorophyll 'b' (mg g^{-1}) content of noni leaves.

Treatment	Vegetative stage					Flowering stage					Harvesting stage				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	0.503	0.593	0.604	0.418	0.530	0.541	0.637	0.642	0.468	0.572	0.566	0.676	0.679	0.492	0.603
S_2	0.527	0.648	0.659	0.449	0.571	0.554	0.693	0.709	0.476	0.608	0.579	0.740	0.758	0.501	0.645
S_3	0.485	0.563	0.552	0.395	0.499	0.532	0.607	0.594	0.419	0.538	0.560	0.638	0.627	0.438	0.566
S_4	0.520	0.705	0.677	0.460	0.591	0.570	0.772	0.725	0.498	0.641	0.596	0.840	0.781	0.519	0.684
S_5	0.497	0.579	0.570	0.403	0.512	0.522	0.611	0.619	0.431	0.546	0.549	0.645	0.654	0.452	0.575
S_6	0.512	0.640	0.629	0.431	0.553	0.548	0.680	0.671	0.465	0.591	0.571	0.725	0.716	0.486	0.625
S_7	0.538	0.617	0.621	0.471	0.562	0.579	0.653	0.659	0.494	0.596	0.607	0.693	0.702	0.513	0.629
S_8	0.310	0.326	0.331	0.246	0.303	0.329	0.342	0.350	0.262	0.321	0.341	0.353	0.362	0.275	0.333
Mean	0.487	0.584	0.580	0.409	0.515	0.522	0.624	0.621	0.439	0.552	0.546	0.664	0.660	0.460	0.582
	M	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**	
SE(d)	0.003	0.004	0.008	0.008		0.003	0.004	0.001	0.008		0.003	0.004	0.009	0.009	
CD at 5%	0.009	0.008	0.017	0.016		0.010	0.008	0.018	0.017		0.010	0.009	0.019	0.018	

Table 9. Effect of different water regimes and organic manures on total chlorophyll (mg g^{-1}) content of noni leaves

Treatment	Vegetative stage					Flowering stage					Harvesting stage				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	1.754	1.963	1.989	1.579	1.821	1.961	2.214	2.230	1.756	2.040	2.148	2.409	2.414	1.911	2.221
S_2	1.813	2.083	2.107	1.627	1.908	1.996	2.349	2.382	1.779	2.127	2.196	2.568	2.601	1.929	2.324
S_3	1.715	1.884	1.869	1.512	1.745	1.937	2.133	2.102	1.670	1.961	2.124	2.331	2.294	1.801	2.138
S_4	1.797	2.223	2.142	1.643	1.951	2.028	2.554	2.407	1.834	2.206	2.219	2.818	2.624	1.986	2.412
S_5	1.741	1.924	1.912	1.548	1.781	1.919	2.162	2.186	1.694	1.990	2.089	2.364	2.380	1.836	2.167
S_6	1.778	2.061	2.037	1.602	1.870	1.982	2.320	2.306	1.740	2.087	2.166	2.537	2.512	1.890	2.276
S_7	1.836	2.011	2.022	1.678	1.887	2.057	2.267	2.278	1.812	2.104	2.245	2.443	2.469	1.963	2.280
S_8	1.236	1.264	1.283	1.129	1.228	1.349	1.380	1.398	1.231	1.340	1.457	1.489	1.510	1.339	1.449
Mean	1.709	1.927	1.920	1.540	1.774	1.904	2.172	2.161	1.690	1.982	2.081	2.370	2.351	1.832	2.158
	M	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**	
SE(d)	0.009	0.013	0.026	0.026		0.011	0.014	0.029	0.029		0.012	0.016	0.032	0.031	
CD at 5%	0.030	0.026	0.057	0.053		0.034	0.030	0.064	0.059		0.037	0.032	0.069	0.064	

Table 10. Effect of different water regimes and organic manures on soluble protein (mg g^{-1}) content of noni leaves.

Treatment	Vegetative stage					Flowering stage					Harvesting stage				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	11.06	12.09	11.92	9.58	11.16	12.80	14.16	13.88	10.49	12.83	11.66	12.81	12.54	9.75	11.69
S_2	11.24	12.84	13.07	9.80	11.74	12.87	14.92	15.14	10.79	13.43	11.70	13.50	13.68	10.02	12.23
S_3	10.75	11.72	11.64	9.26	10.84	12.34	13.61	13.49	10.21	12.41	11.29	12.33	12.27	9.52	11.35
S_4	11.32	13.68	13.21	9.86	12.02	13.04	15.84	15.36	10.92	13.79	11.80	14.42	13.88	10.07	12.54
S_5	10.82	11.86	11.80	9.44	10.98	12.31	13.76	13.68	10.40	12.54	11.33	12.50	12.39	9.70	11.48
S_6	10.91	12.66	12.61	9.67	11.46	12.58	14.83	14.72	10.62	13.19	11.58	13.43	13.29	9.89	12.05
S_7	11.37	12.29	12.43	9.97	11.52	13.12	14.41	14.56	11.06	13.29	11.83	13.06	13.14	10.23	12.07
S_8	7.66	8.07	7.94	6.24	7.48	8.29	8.90	8.64	6.71	8.14	7.82	8.33	8.17	6.39	7.68
Mean	10.64	11.90	11.83	9.23	10.90	12.17	13.80	13.68	10.15	12.45	11.13	12.55	12.42	9.45	11.39
	M	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**	
SE(d)	0.059	0.079	0.159	0.158		0.067	0.091	0.182	0.181		0.061	0.083	0.166	0.165	
CD at 5%	0.186	0.162	0.350	0.323		0.213	0.185	0.401	0.371		0.195	0.169	0.366	0.338	

Table 11. Effect of different water regimes and organic manures on total phenol content (mg g^{-1}) of noni leaves.

Treatment	Vegetative stage					Flowering stage					Harvesting stage				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	3.40	4.02	3.96	2.77	3.54	5.06	6.10	6.13	4.11	5.35	3.79	4.96	5.02	2.71	4.12
S_2	3.51	4.32	4.36	2.96	3.79	5.18	6.54	6.57	4.28	5.64	3.97	5.36	5.44	3.02	4.45
S_3	3.37	3.72	3.79	2.75	3.41	4.91	5.82	5.89	4.03	5.16	3.72	4.62	4.71	2.65	3.93
S_4	3.63	4.55	4.41	3.08	3.92	5.39	6.79	6.62	4.40	5.80	4.15	5.63	5.49	3.18	4.61
S_5	3.29	3.88	3.93	2.84	3.49	4.89	6.01	6.08	4.15	5.28	3.64	4.84	4.93	2.76	4.04
S_6	3.48	4.25	4.21	2.92	3.72	5.12	6.51	6.44	4.21	5.57	3.91	5.31	5.27	2.90	4.35
S_7	3.59	4.11	4.13	3.11	3.74	5.32	6.24	6.29	4.47	5.58	4.11	5.14	5.20	3.24	4.42
S_8	2.29	2.47	2.42	2.13	2.33	3.14	3.35	3.26	2.89	3.16	1.86	2.20	1.95	1.60	1.90
Mean	3.32	3.92	3.90	2.82	3.49	4.88	5.92	5.91	4.07	5.19	3.64	4.76	4.75	2.76	3.98
	M	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**	
SE(d)	0.019	0.025	0.051	0.051		0.028	0.038	0.077	0.076		0.022	0.030	0.060	0.060	
CD at 5%	0.060	0.052	0.113	0.104		0.088	0.078	0.168	0.156		0.068	0.061	0.131	0.122	

Table 12. Effect of different water regimes and organic manures on leaf nitrate reductase activity (µg NO_2 g^{-1} h^{-1}) at various stages.

Treatment	Vegetative stage					Flowering stage					Harvesting stage				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	28.06	34.62	34.53	23.40	30.15	32.10	42.17	42.06	24.88	35.30	25.55	36.57	36.43	19.17	29.43
S_2	28.76	35.62	35.78	23.49	30.91	32.40	43.85	43.79	25.07	36.28	26.08	39.68	39.16	20.32	31.31
S_3	27.48	32.68	32.63	22.56	28.84	30.86	37.09	37.02	24.45	32.36	24.07	32.74	32.81	18.43	27.01
S_4	29.35	38.92	36.04	23.77	32.02	33.18	49.06	45.72	25.16	38.28	27.20	45.84	40.17	20.18	33.35
S_5	28.43	34.18	34.10	22.09	29.70	32.17	40.38	40.31	24.21	34.27	25.64	34.65	34.19	18.20	28.17
S_6	28.60	34.81	34.87	22.75	30.26	32.59	42.53	42.66	24.63	35.60	26.53	36.91	36.98	19.03	29.86
S_7	29.27	35.18	35.11	23.86	30.86	33.06	43.60	43.47	25.92	36.51	26.82	39.05	38.90	20.56	31.33
S_8	16.90	17.05	17.38	15.82	16.79	18.03	18.16	18.89	16.79	17.97	14.13	14.56	14.68	12.96	14.08
Mean	27.11	32.88	32.56	22.22	28.69	30.55	39.61	39.24	23.89	33.32	24.50	35.00	34.17	18.61	28.07
	M	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**	
SE(d)	0.151	0.211	0.423	0.422		0.182	0.248	0.497	0.495		0.159	0.211	0.425	0.422	
CD at 5%	0.481	0.432	0.928	0.865		0.579	0.507	1.094	1.014		0.505	0.432	0.938	0.864	

comprising 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) registered the highest nitrate reductase activity of 38.92, 49.06 and 45.84 µg NO_2 g^{-1} h^{-1} in vegetative, flowering and harvesting stages respectively and this was followed by M_3S_4 (125% WRc through drip irrigation + 50% FYM + 50% VC) with 36.04, 45.72 and 40.17 µg NO_2 g^{-1} h^{-1}.

The nitrate reductase activity was found to be the lowest (15.82, 16.79 and 12.96 µg NO_2 g^{-1} h^{-1}) in the treatment combination M_4S_8 (check basin method of irrigation + no manures and no fertilizers) during vegetative, flowering and harvesting stages, respectively.

Yield parameters

Fruit weight

Between the main plot, higher fruit weight (138.73 g) was registered from M2 (100% WRc through drip irrigation) and this was on par with M_3 (125% WRc through drip irrigation) with fruit weight of 138.10 g (Table 13). The fruit weight was found to be the lowest in the treatment M_4 (check basin method of irrigation) with 97.75 g.

Among the sub plot treatments, S_4 (50% FYM + 50% VC) recorded the highest fruit weight of 143.11 g and this was followed by S_2 (100% VC) with 137.04 g. The treatment S_8 (no manures and no fertilizers) exhibited the lowest fruit weight of 64.27 g.

Pertaining to the interaction effects, the treatment combination M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) produced the highest fruit weight (167.86 g) and this was followed by M_3S_4 (125% WRc through drip irrigation + 50% FYM + 50% VC) with 163.44 g.

Among the interactions, the fruit weight was found to be the lowest (58.86 g) in the treatment combination comprising check basin method of irrigation + no manures and no fertilizers (M_4S_8).

Number of fruits per plant

The highest number of fruits were counted in the treatment M_2 (100% WRc through drip irrigation) with 176.04 (Table 13). The lowest number (142.43) was obtained from the treatment M_4 (check basin method of irrigation).

Between the sub plot treatments, an increase in number of fruits (177.63) were obtained from the treatment S_4 (50% FYM + 50% VC) followed by S_2 (100% VC) with 173.14. While the treatment S_8 (no manures and no fertilizers) registered the least number (113.78) of fruits per plant.

In the interaction, the treatment M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) expressed greater number of fruits per plant (198.12) and this was followed by M_3S_4 (125% WRc through drip irrigation + 50% FYM + 50%

Table 13. Effect of different water regimes and organic manures on fruit weight (g), number of fruits per plant and yield per plant (kg).

Treatment	Fruit weight (g)					Number of fruits per plant					Yield per plant (kg)				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	120.24	141.77	143.69	100.88	126.65	161.55	180.94	182.05	145.72	167.57	19.41	25.64	26.14	14.70	21.47
S_2	125.96	156.78	159.74	105.68	137.04	164.84	188.32	190.54	148.86	173.14	20.75	29.51	30.42	15.74	24.11
S_3	115.28	134.26	133.27	95.63	119.61	155.69	171.63	170.52	142.07	159.98	17.96	23.02	22.72	13.57	19.32
S_4	129.25	167.86	163.44	111.88	143.11	165.32	198.12	193.21	153.88	177.63	21.35	33.26	31.59	17.22	25.86
S_5	117.77	140.44	138.72	97.52	123.61	157.75	178.42	175.36	142.88	163.60	18.56	25.08	24.34	13.94	20.48
S_6	123.27	152.43	150.66	104.26	132.66	162.32	187.75	186.83	146.25	170.79	20.02	28.60	28.16	15.24	23.01
S_7	131.69	147.53	148.89	107.25	133.84	167.18	185.34	186.12	152.63	172.82	22.04	27.33	27.70	16.35	23.36
S_8	63.12	68.74	66.35	58.86	64.27	113.88	117.82	116.28	107.12	113.78	7.18	8.10	7.73	6.31	7.33
Mean	115.82	138.73	138.10	97.75	122.60	156.07	176.04	175.11	142.43	162.41	18.41	25.07	24.85	14.13	20.62
	M	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**	
SE(d)	0.326	0.452	0.906	0.904		0.429	0.588	1.180	1.176		0.057	0.078	0.157	0.157	
CD at 5%	1.036	0.926	1.989	1.852		1.364	1.204	2.594	2.408		0.182	0.160	0.346	0.321	

VC) with 193.21. While the lesser number was noted in the treatment M_4S_8 (check basin method of irrigation + no manures and no fertilizers) with 107.12.

Yield per plant

Concerning the main plot, M_2 (100% WRc through drip irrigation) registered the highest fruit yield per plant of 25.07 kg and this was followed by M_3 (125% WRc through drip irrigation) with 24.85 kg (Table 13. The fruit yield per plant was found to be the lowest in M_4 (check basin method of irrigation) with 14.13 kg.

Pertaining to the sub plot treatments, S_4 (50% FYM + 50% VC) produced the highest fruit yield per plant of 25.86 kg and this was followed by S_2 (100% VC) with 24.11 kg. While the treatment S_8 (no manures and no fertilizers) recorded the lowest fruit yield per plant of 7.33 kg.

Among the interactions, M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) registered the superior score for fruit yield per plant of 33.26 kg and this was followed by M_3S_4 (125% WRc through drip irrigation + 50% FYM + 50% VC) with fruit yield per plant of 31.59 kg. Fruit yield per plant was found to be the lowest (6.31 kg) in the treatment combination M_4S_8 (check basin method of irrigation + no manures and no fertilizers).

DISCUSSION

Physiological parameters

Any crop management practice should aim in keeping the physiological process of the plants in an active stage so that the plants can produce biomass with the least destructive processes.

LAI is a measure of vegetative growth of plants and the assimilatory surface on which the production of dry matter takes place. LAI is a positive indication on plant growth with a direct influence. The LAI has a decisive role on physiological parameters like SLW and light interception. Combined application of 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) has led to higher LAI. This may due to continuous and uninterrupted supply of water and nutrients. This finding was strengthened by previous work of Singh et al. (2004) and Umesha et al. (2011).

The plants maintain a turgid condition during the day time under drip irrigation as compared to check basin method of irrigation. There is a possibility of wide opening of stomata for longer period which might have resulted in high exchange of gases. Similarly, leaves might have remained turgid and produced more leaf surface. Thus, in turgor state helps in absorption of more sun light and solar radiation. It has resulted in higher rate of photosynthesis and increased the photosynthetic capacity, which ultimately might have resulted production of more LAI and in turn the light interception for photosynthesis. The crops experienced water stress period before each irrigation under check basin method irrigation due to the availability of moisture and nutrients were limited for the roots to absorb. As results, there is reduction in LAI and light interception.

The higher LAI and light interception as a result of maintenance of favorable soil moisture in the root zone and effective absorption by plants. The optimum P uptake and greater P mobility through frequent or continuous low volume irrigation can maintain three dimensional distribution patterns of water and nutrients and provide improved conditions for growth and water and nutrient uptake (Gal and Dudley, 2003).

Similarly the higher LAI and light interception may due to the optimum uptake of nutrients especially nitrogen, iron and magnesium from the soil resulted in more chlorophyll content which might have enhanced the photosynthetic rate and production of more leaf area inturn light interception for photosynthesis (Khandkar and Nigam, 1996).

The application of FYM in the treatment would have increased the friability, promoted aggregation of soil and increased the level of humus, thereby increasing the microbial activity. This in turn would have enhanced the increased production of more photosynthates due to enhanced photosynthesis leading to more accumulation of carbohydrates. This may be responsible for increased LAI, light interception and SLW.

Furthermore, inoculation of the biofertilizer, *Azospirillum* would have increased the activity of root exudates which in turn might have accelerated the activity of beneficial microbes by higher nitrogen fixation and secretion of growth promoting substances as reported by Okon and Kapulnik (1986) which owed to the luxuriant growth of vegetative parameters that was reflected on improved LAI.

In the present experiment 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) exhibited the highest SLW. SLW was considered to be a good indicator of photosynthetic capacity of the leaf (Wallace et al., 1972). The highest SLW was mainly due to minimum water stress and better nutrient availability developed by low rate of evapotranspiration and minimum nutrient loss under drip irrigation system. These results are similar to the findings of Rao et al. (2000) in tomato and Shoba (2009) in black nightshade (*Solanum nigrum*).

A higher photosynthetic activity is a good indication of physiological efficiency in plants. This primarily depends upon the leaf chlorophyll content. The chlorophyll content in leaves indicates the efficiency of photosynthesis where the solar energy is converted into chemical energy. A slight fluctuation in chlorophyll is enough to trigger changes in physiological processes of the plants particularly photosynthesis.

The chlorophyll content was significantly higher in the treatment combination comprising 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) as compared to check basin method of irrigation + no manures and no fertilizers (M_4S_8). The amount of chlorophyll present has a direct relationship with the rate of photosynthesis. Hence, an increase in biomass production was obtained by higher chlorophyll content in plants.

Such increase may be due to optimum water absorption and optimum uptake of nutrients which have close association with chlorophyll biosynthesis as reported by Raghavendra (2000). Similarly, the presence of humic substances in FYM was the additional source of polyphenols that might have acted as respiratory catalysts, which in turn enhanced the rate of respiration and metabolic activity of the plants and thereby increasing the chlorophyll content (Padmanabhan, 2003).

The reduced chlorophyll content in check basin method of irrigation + no manures and no fertilizers (M_4S_8) may due to high moisture stress and poor nutrient availability. This situation cause delay in chloroplast membrane synthesis (Hinningsen, 1970) which can be a reason for reduced total chlorophyll content. Also, water stress and nutrient deficient condition causes a reduction in synthesis of precursors of chlorophyll (Mukhmudov, 1983) which in turn reduce the chlorophyll content.

The soluble protein content in leaves indirectly indicates the photosynthetic efficiency of the crop. Since, it constitutes more than 70% of the RuBp carboxylase, the enzyme responsible for CO_2 fixation in photosynthesis (Nogle,1979). An increase in soluble protein content denotes the increasing ability of plants to fix CO_2 effectively. Hence, a level of soluble protein content is considered as an index for the assessment of photosynthetic efficiency. The treatment combination M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) registered the highest soluble protein content. This might be due to high soil moisture status, thus maintaining normal cell integrity, cell elongation and functioning of biopolymers apart from optimum nutrient uptake.

Phenols are the physiologically active secondary compounds produced by all the higher plants and perhaps by each cell of the plant. They can be found in the cytoplasm, vacuoles and cell walls and the sites of their biosynthesis indicate the potential importance of these compounds in plant’s life (Zaprometov, 1989). Hence deposition of more structural proteins and phenolics in the cell wall regions would directly influence the resistance mechanisms. The present study indicates that application 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) resulted in increased phenol content. It could be attributed to the fact that phenols induce resistance to pathogens by the production of PR (plant resistance) proteins (Raskin, 1992).

Moreover, the humic substances present in FYM and VC are known to contain phenyl alanine; the precursor for several phenolic substances would also have contributed to the increase in the phenol content (Padmapriya, 2004).

Combined application of 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) recorded the highest nitrate reductase activity.

Application of water at frequent time interval through drip irrigation maintains the soil moisture, prevents the plant from soil moisture stress and keeps the plant always in physiological active state which would have resulted in higher nitrate reductase activity. Similar trend of results have been documented by Sachdev et al. (1987) and Prakash (2010).

Mahadevan (1988) suggested that, high nitrate reductase activity indicates a higher level of protein synthesis and accumulation of soluble protein. This in turn indicates that nitrogenous compounds in the plants are well utilized for various metabolic activities. Major part of soluble protein consists of RUBISCO enzyme, which is carboxylation as well as oxygenation enzyme. This is very essential for the fixation of atmospheric CO_2 to produce carbohydrates. Therefore, if the soluble protein is high, photosynthetic efficiency will be more, which may result in better yield.

This may be also due to the fact that VC is a loosely packed, granular aggregate of enzymatically digested organic matter containing essential nutrients in easily available or mineralisable form. So, when VC was added to the soil, it enhanced the soil microbial activity and provided essential macro and micro nutrients for better crop growth. Besides, earthworm casts have been shown to stimulate nitrate reductase activity, which regulates the nitrate availability for the plants (Jat and Kumar, 2002).

Yield parameters

The ultimate goal of any management practice is to improve the yield level with minimal cost of production. The system has to be maintained as such without letting any sort of degradation in soil, water or environment besides obtaining quality produce. The experimental plots receiving 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) recorded the highest fruit weight.

Drip irrigation at optimum level provides a consistent moisture regime in the soil due to which root remains active throughout the season resulting in optimum uptake of water and nutrients. This facilitates proper translocation of food materials which accelerates the fruit growth and development in noni. The highest fruit weight under drip irrigation might be ascribed to better water utilization, minimum losses of water through percolation and evaporation and excellent soil-water-air relationship with higher oxygen concentration in the root zone and optimum uptake of nutrients. These results are in agreement with the findings of Bafna et al. (1993) and Prakash (2010).

This could be also due to the slow release of nutrients in synchrony with improved physical properties of soil resulting in optimum uptake of nutrients, which might have facilitated improvement in fruit characters particularly particularly fruit weight. In addition to this, FYM has favoured the supply of micronutrients through its own decomposition, besides acting as an additional source of ammoniacal nitrogen ultimately resulting in increased fruit weight. FYM improved soil physical structure and texture, decreased the bulk density and increased moisture retention. All these comprehensive changes paved the way for greater fruit weight.

Moreover addition of biofertilizers and soil beneficial rhizosphere microflora produces organic acids viz, malic and succinic acids which convert insoluble soil phosphates to more soluble compounds thereby increasing the availability of nutrients. This increased nutrient availability could have resulted in higher accumulation of carbohydrates in sink thereby exerting a remarkable increase in fruit dimensions.

Number of fruits is an important character that decides the yield of the crop. It was observed in the present study that the highest number of fruits per plant was obtained with the treatment combination comprising 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4). Better availability and utilization of nutrients and water may be the possible reason for the promotary effects.

Roots can easily translocate absorbed water from the soil where available soil moisture content was optimum at 100% WRc through drip irrigation. Required energy for water absorption was less under this treatment and ultimately led to easy energy translocation to the reproductive parts. Application of FYM and VC had increased the soil organic matter and improved the soil structure and biological activity of the soil. This would have reduced the loss of nitrogen by increased cation and anion exchange capacities in soil thereby enhancing the fruit development and yield (Ayisha, 1997).

The pronounced yield improvement in organic treatment might be due to sustained availability of nitrogen in the soil throughout the growing phase and also due to enhanced carbohydrate synthesis and effective translocation of these photosynthates to the sink, that is, fruit, while at lower fertility levels plants remained stunted resulting in decreased yield.

Drip irrigation maintains the soil moisture around the field capacity between two irrigation intervals. On the other hand, check basin method of has high fluctuation of moisture between field capacity and permanent wilting point. This might have resulted in lower fruit yield under check basin method of irrigation. These results collaborate with the findings of Aladakatti et al. (2012) and Behera et al. (2012).

The reduced moisture availability in M_4S_8 (check basin method of irrigation + no manures and no fertilizers) creates water stress condition. As water stress increases, CO_2 assimilation per unit leaf area decreases. When soil moisture stress intensifies, photosynthesis gets restricted to few hours and peak rate reduces. As a result biomass accumulations become slower (Suanez et al., 1989).

Water stress generate active oxygen species which are extremely reactive and cytotoxic and it can affect the respiratory activity in mitochondria, can cause pigment break down and thereby less of carbon fixing capacity of chloroplasts (Scandalios, 1993). As result there is reduction in fruit number and fruit yield.

From the present study, it could be concluded that application 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) produced the highest and sustainable crop yield through improved physiological efficiency of noni plants.

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